Understanding the Socio-Technical Impact of Automated (Aerial) Vehicles on Casual Bystanders

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ABSTRACT

Automated vehicles are coming to our streets and into our air. These automated vehicles are not acting as fully independent entities but are embedded into our social space and are affecting humans with which they interact. Recent advances are looking at the direct cooperation of human and machine in concrete interaction scenes such as steering a semi-automated drone or interacting with an automated car as a pedestrian. What we do not understand yet, is the reaction of automated systems on individuals that are casual bystanders of the automated systems. Cooperation and social acceptance of the casual bystanders are crucial in many situations. Affects such as irritation, anxiety or frustration may be easily invoked by the automated object. We need to anticipate effects on bystanders and include this into the interaction design space.

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Figure 1: Person interacting with a drone showing it to move sideways.

Figure 2: Person interacting with automated vehicles in a VR Simulation - interacting with an automated vehicle to indicate it should give way.

CCS CONCEPTS

• **Human-centered computing** → **Interaction paradigms**.

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INTRODUCTION

Understanding an automated vehicle is challenging and can cause negative side effects, such as anxiety or frustration. Because today's automated vehicles omit the human side of person-to-person communication: when communicating with an automated vehicle, users and bystanders cannot rely on established practices as in communicating with other individuals. While the automated vehicles of today are being designed to work properly, robustly and safely, they do not yet act socially. Two humans that can see each other, such as a pedestrian and a driver, still use many subtle cues to cooperate and indicate each others intention. This may not be true for a full automated vehicle in cooperation with a pedestrian, who may not understand it, not trust it, or just be surprised by the automated vehicles' behavior. Similarly, drones might distract or surprise bystanders and even cause anxious behavior, as when a drone approaches a person that is not expecting it and cannot understand the intention of the drone.

We propose that a systematic exploration of the design space is needed for automated vehicles. This includes their appearance and actions to communicate intent to casual bystanders in everyday situations and increase cooperative, prosocial behavior. We hypothesize that bystanders and affected persons not only need to recognize the automated vehicle but clearly understand its intentions and upcoming actions to increase social acceptability and successful cooperation.

STATE OF THE ART

The interaction between humans and drones is a field in its beginning. Nevertheless, drones are more and more becoming automated (aerial) vehicles. We are convinced that the work on interaction between other types of automated vehicles and pedestrians and other traffic participants will be inspiring and supporting for the work on human-drone interaction. Research and industry are already making first proposals and showcase concept studies of communicating with bystanders to inform them and to keep them in the loop. In consequence it is timely and topical to conduct research on the effect of (automated) drones on casual (human) bystanders.

Rothenbücher et al. [26] developed a Wizard-of-Oz technique for investigating the interaction between automated vehicle and traffic participants (or bystanders) by hiding the actual driver (the "Wizard") of the car. They considered how pedestrians interacted with the car at crossings in the

Stanford University Campus and found that most pedestrians were able to decide whether to cross the road or not without explicit communication, but also that it remains relevant to acknowledge that a pedestrian was noticed. However, this was a first experiment in a confined campus setting where people are expectedly open to technological innovations and with less of a surprising effect than in a narrow urban road scenario in Europe. Similarly, Petterson et al. [23, 24] report on explorations of social situations between (seemingly) autonomous cars and pedestrians using similar techniques where the actual driver was hidden behind a cover resembling a car seat (c.f., Habibovic et al. [14]). They uncovered two-fold, specific information needs: information the pedestrian may need from the autonomous vehicle in certain situations, and vice versa. Chang et al. [8] equipped cars in Virtual Reality (VR) with eyes to help pedestrians assessing if they were acknowledged. Their experiment showed that pedestrians made quicker decisions and felt safer when they could see where the car is "looking". Mahadevan et al. [19] explored possible interfaces and designs for explicit vehicle-pedestrian communication and tested them with an equipped car and a Segway. They could show that explicit signals help pedestrians to make faster decisions. While reviewing, relevant literature shows that research towards cues and signaling of automated vehicles exists, there are still no common communication strategies or even standardized designs. Also, current research focuses on functional traffic interaction such as crossing a road but does not necessarily investigate how cues need to be designed for prosocial behavior and inclusion of effects on casual bystanders.

The social acceptability of drones as guidance vehicles for navigating persons with visual impairments has been explored by Avila Soto et al. [1]. They investigated both, the (visually impaired) user's perspective, and the perspective of (sighted) casual bystanders, and note that knowledge about the purpose, functioning, and benefits of the guidance drone are relevant for social acceptability. However, they did not elaborate on autonomous behavior of the drone and on how the drone interface might communicate its intent. Communication of usage purpose and intention has been explored in the area of body-worn cameras [18]. In this context, design strategies including physicality, signaling, as well as transfer of control have been explored to create a sense of situational awareness for the bystander, and justification on the device user's side. The authors also explored how bystanders can take over control by using gestures to explicitly express consent (Opt-in) or disapproval (Opt-out) with being recorded by a body-worn camera [17]. Similar technologies could be used for drones when people might want to use explicit consent to be recorded or not.

In our own previous work, we have been designing and evaluating multimodal interfaces that form the foundation for communicating information about upcoming tasks and objects in pervasive spaces by multimodal cues. We systematically explored different sensor modalities in pervasive user interfaces: light-based interfaces [20], projection-based interfaces [4], auditory interfaces [16], and haptics and vibro-tactile interfaces [5, 25, 27]. For many years now, we explored assistance systems with increasing levels of automation. We studied the effect of multimodal cueing for situation awareness and spatial awareness in supervisory tasks [10] and attention shifting to other work tasks [21]. We studied how wearable technology can give feedback on biosignals using visual, audio, and haptic modalities [11]. We have been designing multimodal cues for take over in highly automated driving [2] and priming individual with information about the upcoming task after taking over [3]. In recent work, we investigated how we can shift attention in larger cyber-physical system and environments to (automated) objects that are currently out of view [13, 28].

To date, research on human-drone interaction has aimed to communicate the intent of a drone, such as using LEDs around a quadcopter to communicate direction [30] or modifying the drone's flight path, using techniques such as arcing, to communicate directional intent [29]. We find that several works that looked at the adequacy of multimodal interaction with drones [6], or how drones might convey information about themselves. As one example, Cauchard et al. [7] modified the flight path of the drone to communicate the drone's emotions. However, none of this work investigated the automation level of the drone and how it could handover control to passersby or provide the option to listen to their command. As with autonomous cars, the technology's current level of automation for a task is not conveyed to passersby. It is crucial for the autonomous vehicles to become more transparent so that they can be accepted into our environments. In order to explore concepts and interaction designs, this research can be inspired by different levels of simulation of automated situations which enables us to obtain higher levels of mundane realism [23], to evaluate designs for interaction with automated vehicles in different traffic scenarios.

PROSOCIAL BEHAVIORS IN HUMAN-AUTONOMOUS VEHICLE COMMUNICATION

So far, research and industry has shown interesting prototypes and design concepts of such displays outside the vehicle. However, commercial products coming with a standard set of communication patterns have not been developed. Here, the industry has not yet demonstrated a clear understanding of a cooperative and understanding interaction between automated vehicles and individual bystanders. To better understand the impact of the role of bystanders for the design of automated (aerial) vehicles for acceptance and cooperation of automated vehicles with casual bystanders we need to understand how an automated (aerial) vehicle and its goals can be recognized and understood. We need to design for prosocial behavior with the automated vehicle and how cues and signals of the automated vehicles can support cooperative behavior and communication with bystanders. We identify three core aspects of that form the basis for a successful interaction between an automated vehicle and bystander(s):

Situational Awareness (SA)

One aspect is the Situation Awareness of the automated vehicle by the bystander. We are following Endsley's well established notion of Situation Awareness [9], in which SA comprises the perception of the objects in the environment, understanding their behaviour and the individuals' projection of future states and events. We propose that the following questions need to be answered to understand which cues and signals issued by the automated vehicle are good prerequisites to increase the situation awareness of the vehicle:

- How to make the bystander aware of the automated (aerial) vehicle?
- How to allow the bystander to identify whether a present automated (aerial) vehicle is affecting her/him?
- How can one tell what the automated (aerial) vehicle does and for what purpose and by whom?

Affordance

Based on the longstanding knowledge from the field of human computer interaction, we know that interaction is more successful and satisfying if the object of interaction offers affordance on how to interact with it [22]. As an attribute of interaction design, an affordance is a feature that is offered to the user, what the interaction design provides or furnishes [12]. We want to understand what kind of physical (real) affordance, cognitive (perceived) affordance, and functional affordance [15] the automated vehicle can offer to the bystander, such that it easily reveals its functions and actions. With such an affordance concept, the bystander can understand if and how they may be able to interact with the automated (aerial) vehicle such as allowing it to come closer or to stop.

- Do the automated (aerial) vehicle's features help the bystander to understand what it does/and provides?
- Does the automated (aerial) vehicle reveal if it is ready to receive inputs and if a bystander may interact with it?
- Does the automated (aerial) vehicle offer functions to interact with it?

Conversation

The interaction with an automated vehicle might not be a one-shot or uni-directional interaction, but rather an actual negotiation between an individual and an automated (aerial) vehicle. For example, in the case of a car, the determination of who will go first and decide that the individual may interfere and signal a decision (c.f., Figure 2). In the case of a drone, the person may want to tell the drone that they do not want to appear in recorded footage, provide instructions for guidance and navigation aids, or acknowledge receipt of a delivery.

- How does the automated (aerial) vehicle get into a conversation with a bystander?
- How can the bystander ask and get explanations on the intentions and actions of an automated (aerial) vehicle?
- How to interact with the automated (aerial) vehicle such as asking it to come closer?

Key Factors

We hypothesize that are three key factors that are core to such communication aspects for moving automated vehicles, such as cars and drones, as described above. These core factors, that we envision to be addressed by future research are:

(1) Physicality. The device itself may have a form, shape and (aesthetic) appearance that is self-explaining its functions and potential actions. What role does the shape of the device play for the acceptance of the automated devices' actions? Can the intended function already be encoded in the appearance?
(2) Signaling. Beyond the actual appearance, the device can use integrated and added displays to signal its behavior to the bystander. It needs to be further investigated what and how should it signal with visual and auditory displays?
(3) Movements. As the automated vehicle is moving, it is in demand to better understand how to express cooperative behavior with movements. How should such vehicles approach a person to express intent of communication?

CONCLUSION

HCI research with autonomous devices is still in its early stages. Autonomous cars are increasingly being studied and have an obvious widespread reach as we saw companies like Uber using autonomous taxis driving passengers from 2016 to 2018. On the other hand, drones are just reaching the point of technological maturity for them to interact with people. We posit that the research done in autonomous devices can be designed with similar methodologies for cars and drones. In particular, we show the importance of including methodologies taking in consideration passerby and not only designated users. This will be crucial for the technology to become acceptable to all.

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